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ECOLOGY OF AN ENDANGERED *GENTIANA FLAVIDA* POPULATION IN EAST-CENTRAL KENTUCKY

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ABSTRACT

An ecological study of a population of the Kentucky-endangered *Gentiana flavida* was conducted in a 0.11 ha (1100 m^2) macroplot in Madison Co., Kentucky. Cream gentians occur in a mesic prairie inclusion meadow and mixed hardwood-red cedar forest edge on a southwest-trending rocky lower slope. They occur in low foliage coverage (8%) and do not thrive well under total shade compared to partial shade or full sun. The population is threatened by exotic invasive taxa (mainly the grasses *Arthraxon*, *Microstegium*, and *Schedonorus*), encroachment of woody plants from the forest edge, and potential herbicide-spraying along a powerline corridor that passes through the macroplot. In a floristic survey of the macroplot, 211 vascular plants species (192 native, 19 non-native) in 156 genera were recorded; 143 species were identified in 30 (1 m^2) quadrats; 68 species in the macroplot did not appear in quadrats. Sixteen of the 19 exotic naturalized taxa are state-listed invasives.

We studied aspects of the biology and ecology of a population of *Gentiana flavida* A. Gray (cream gentian) in southeastern Madison Co., Kentucky, within the Eastern Knobs Region of the Western Alleghany Plateau (Figure 1). The cream gentian is an endangered species in Kentucky, observed only in five counties from wet calcareous prairies and open woodlands (KSNPC 2017). The present overall distribution is restricted to small isolated populations in 13 Midwestern states and one extant population in Ontario, Canada (Pringle 2017; Figure 2).

The 0.11 ha (1100 m^2) Madison County macroplot is rectangular-shaped and situated on private land from 243 to 248 m elevation above sea level at latitude 37.60273° N and longitude 84.15260° W (Figure 1). Our study was made from August 2013 to October 2014 and from April to September 2017. Jean's Glade, the study site, is named to honor the memory of Jean Horrar, the landowner who initially preserved the gentian population. The present article provides the first descriptive ecological and floristic study for a Kentucky cream gentian population.

Morphology and phenology

Gentiana flavida is a glabrous, native perennial forb from 40 to 95 cm tall from a stout unbranched stem and a long, thick taproot (Pringle 1963, 1965, 1967; Wood & Weaver 1982). Plants produce 1–10 erect ramets with a laxly erect to sprawling habit, where several mature stems arise from older rootstocks (Pringle 1965; Figures 3, 4, 5, 6). In Kentucky, flowering begins in early August through October and concludes with seed dispersal from capsule dehiscence in late October–early November. Pollination is effected by bumblebees (*Bombus* spp.).

Taxonomy

Gentiana flavida is one of 13 *Gentiana* species in sect. Pneumonanthae, tribe Gentianeae, family Gentianaceae, within eastern North America (Pringle 1967) and one of 27 *Gentiana* species treated in the *Flora of North America North of Mexico* (Pringle 2017). The correct scientific name of the cream gentian has been of considerable debate (Pringle 1963, 1965, 1967, 2017; Wilbur 1988; Gandhi, Greuter, & Wiersema, pers. comm. 2017). Muhlenberg (1813) named the cream gentian (*Gentiana alba* Muhl.) but did not provide a description (Wilbur 1988; Gandhi, Greuter, & Wiersema, pers. comm. 2017). The name *G. alba* Muhl. ex Nutt. has often been cited, but Nuttall (1818) but gave no validating information beyond Muhlenberg. Gray (in Gray & Sullivant 1846) validly named the cream gentian as *G. flavida* A. Gray.

Several common names have been used for *Gentiana flavida*, largely based on various flower colors: white gentian, white plains gentian, white prairie gentian, pale cream gentian, pale gentian, plains gentian, yellowish gentian, and yellow gentian (Waldron 2001; Heikens 2002; Bowles & Jacobs 2010; Bebeau 2014; Pringle 2017).

Geographic distribution

Gentiana flavida is native to eastern North America in the midwestern and eastern USA and Ontario, Canada (Pringle 1963, 1967, 2017; Kartesz 2015; NatureServe 2017; Figure 2). Cream gentian populations are imperiled throughout much of their distribution range because of extreme habitat losses primarily from anthropogenic disturbances, forest expansion, absence of fire, and invasive grasses and forbs. The overall decline of eastern populations has been affirmed, and the continued existence of peripheral populations surviving as isolated prairie remnants has significantly decreased in recent years (Pringle 1963, 1967, 2017).

Figure 1. *Gentiana flavida* in Jean's Glade, among foreground mesic prairie inclusion meadow and background subxeric mixed hardwood-red cedar forest edge.

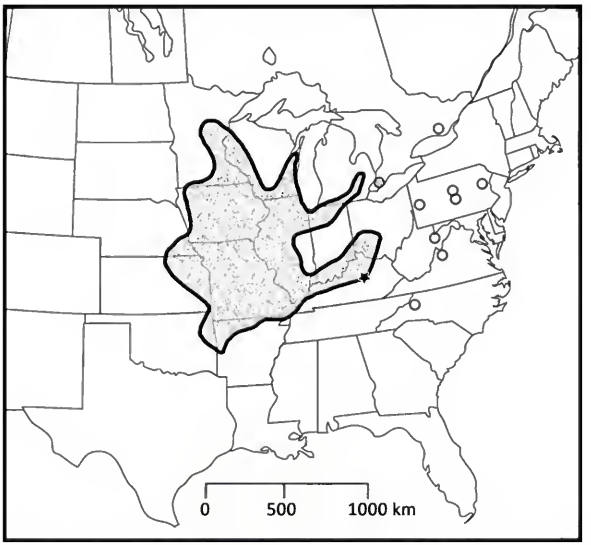

Figure 2. Present-day distribution (shaded outline) of *Gentiana flavida* in the USA and Canada and extirpated populations (hollow circles), after Pringle (1967, 2017). A disjunct relic Ontario population lies above Lake Erie and below Lake Huron. A star symbol marks the Madison County site in east-central Kentucky.

Figure 3. *Gentiana flavida* genet with several unbranched, sprawling ramets in the mesic prairie inclusion meadow.

Figure 4. *Gentiana flavida* with simple, opposite cauline and whorled terminal leaves (*Thompson 17-480*, BEREA).

Figure 5. Terminal and axillary inflorescences of *Gentiana flavida* with two brown marcescent axillary flowers (*Thompson 17-480*, BEREA)

Figure 6 *Gentiana flavida* terminal inflorescence of partially open corollas adapted to bumblebees (*Thompson 17-480*, BEREA).

Pringle (1963) inferred that the original center of populations for *Gentiana flavida* was west of the Mississippi River, possibly the Ozark Highlands, with the gentian migrating eastward with the expansion of tallgrass prairie vegetation during the post-Wisconsin xerothermic period, and that the current eastern populations are prairie relicts or prairie remnants, as evidenced by wide-ranging native tall grasslands where most extant populations are found.

The North American *Gentiana flavida* distribution (Figure 2) formerly extended from Arkansas, Oklahoma, Missouri, Kansas, Nebraska, Iowa, Minnesota, Wisconsin, Michigan, Illinois, Indiana, Kentucky, Ohio, to scattered outlier populations in Maryland, Pennsylvania, West Virginia, Virginia, North Carolina, and Ontario, Canada (Pringle 1963, 1967; NatureServe 2017; USDA, NRCS 2017). The current USA range extends from Arkansas, Oklahoma, Missouri, Kansas, Nebraska, Iowa, Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, and Kentucky (Pringle 1967, 2017; Figure 2). Outlier populations in North Carolina, Pennsylvania, Virginia, and West Virginia have been extirpated (Figure 2), and a Maryland report was erroneously based upon a misread specimen label from Indiana (Pringle 2017). Kartesz (2015) mapped Pennsylvania and North Carolina as extirpations. The distribution map of *G. flavida* (Figure 2) illustrates the one relic population remaining above Lake Erie in southwestern Ontario (Waldron 2001; Bowles & Jacobs 2010) and the 13 USA historic records (Pringle 1967, 2017).

Habitats

Principal habitats of the cream gentian are calcareous substrates with vegetation dominated by native warm-season prairie grasses and forbs (Pringle 1965; 2017; Heikens 2002). Pringle (1965) determined that *Gentiana flavida* is an obligate calciphile prairie species. Hilty (2008) recorded gentian habitats in Illinois from mesic prairies, sandy oak savannas, rocky bluffs, upland forest edges, and limestone glades. Calcareous gentian habitats in Missouri include rocky prairies, rocky wooded slopes, rocky open limestone and cherty limestone glades and bluff escarpments (Steyermark 1963; Yatskievych 2013). Andreas and Cooperrider (1981) reported the species in Ohio from upland mesic prairies, glades, open upland forests, prairie openings, and grassy fields. In Minnesota, Bebeau (2014) indicated that cream gentian grows in well-drained soils of moist meadows, prairies, and open woodland habitats under partial shade or full insolation. At Walpole Island, Lambton County, Ontario, the last extant Canadian population is restricted to a remnant of mesic to dry oak-hickory savannah in calcareous soils (Waldron 2001; Bowles & Jacobs 2010).

Campbell and Medley (2012) noted that cream gentian occurs in native grassland remnants, usually in damp limestone-based soils, in Kentucky. Actual documentation in the last 30 years has only been from the Eastern Knobs and the Bluegrass Regions (Campbell & Medley 2012). Although Kartesz (2015) mapped ten Kentucky counties, the Kentucky atlas by Campbell and Medley (2012), mapped only Robertson and Rowan counties from voucher specimens with non-verified reports from Butler, Lewis, Logan, Madison, Pendleton, and Warren counties. The western counties, Butler, Logan, and Warren, are doubtful without actual specimen documentation (Campbell & Medley 2012). The KSNPC (2017) reports Butler and Warren counties as historic observations and records the gentian from past observations in Lewis, Madison, Nicholas, Robertson, and Rowan counties, but without any voucher specimens.

Kentucky documentation

Prior to the population assessment at the Madison County site, actual specimen documentation has been verified from only three counties on soils derived from Ordovician limestone or Silurian limestone and dolomite in east-central Kentucky. A historic Pendleton County specimen near Falmouth was collected in September 1931 within the Hills of the Bluegrass Ecoregion (*Barton s.n.*, BEREA!, KY!). In 1985, Medley (1993) collected a cream gentian in Robertson County in a rocky limestone prairie of a cedar glade woodland at Blue Licks Battlefield State Resort Park within

the Hills of the Bluegrass Ecoregion (*Medley 13564-85*, DHL! now at APSC). A third specimen was collected on 16 September 1987 from a population on an open grassy ridgetop in limestone soil near Clearfield, Rowan County, within the Western Allegheny Plateau (*Hammer 538*, EKY!). The first Madison County collection from our study area in Silurian-derived calcareous soils was 21 August 2002, within the Knobs-Lower Scioto Dissected Plateau Ecoregion of the Western Allegheny Plateau (*Thompson 02-392*, BEREA!).

Conservation rankings

The KSNPC (2017) classifies *Gentiana flavida* for the Kentucky State Protection Status as an Endangered species. NatureServe (2017) ranks it in Kentucky as S1S2 (critically imperiled to imperiled). The species is classified a Global rank of G4 (apparently secure) and a national rank of N1 (critically imperiled). In Ontario, the single mesic oak-hickory savannah population is ranked S1 (critically imperiled), and Nationally Endangered (Waldron 2001; Bowles & Jacobs 2010). The cream gentian is listed as SH (historic) in North Carolina and Pennsylvania and S1 (critically imperiled) in Michigan, Nebraska, Oklahoma, and West Virginia, S2 (imperiled) in Indiana, Kansas, and Ohio, and S3 (vulnerable) in Iowa and Wisconsin. Arkansas, Illinois, Minnesota, and Missouri are SNR (rank not yet assessed); populations in those states are presumed secure (NatureServe 2017). Extirpated populations in North Carolina, Pennsylvania, Virginia, and West Virginia have provisional SH (historic) rank status (Pringle 2017; Figure 2), although these states are not all currently mapped as extirpated by Kartesz (2015), NatureServe (2017), and USDA, NRCS (2017).

THE GENTIAN STUDY SITE

Physiographic Ecoregions

The Knobs Region is a narrow horseshoe-shaped belt of rugged east and west mountain topography typically known as "Knobs." The Knobs, marked as Eastern and Western Knobs, encircle the Kentucky Outer Bluegrass Region (Burroughs 1926; Fenneman 1938). These conical knobs (erosion remnants) are numerous, flat-topped, or domed-shaped with concave upper slopes at lower elevations due to capstone Pennsylvanian escarpments remaining after easily eroded shale and siltstone have been severely cut by streams over time (Fenneman 1938; McFarlan 1943; Newell 1981; Muller & McComb 1986). The Knobs characteristically occupy narrow valleys to broad alluvial floodplains of first-order and second-order streams dissecting the nearby escarpments. A thick colluvium emerges on lower hillside slopes to form alluvial floodplains on V-shaped valleys and eventually to U-shaped valleys (Newell 1981).

Campbell (2003) mapped the physiography of the Knobs Region based on soils, geology, topography, vegetation, and biogeography. He described the Kentucky Ecoregional Sections in the vicinity of Jean's Glade, as the Knobs Region and Transitions, which are situated between the Eastern Bluegrass to the west and the Black Shale-Siltstone Knobs of the Appalachian Plateau to the east. To be more precise, the environs with the gentian site are located within the Dolomitic Plains and Foothills and Foothill Flats and Knob Valleys Sections from Campbell (2003).

Woods et al. (2002) designated the Knobs Ecoregions as belonging to the Knobs-Lower Sciota Dissected Plateau of the Western Allegheny Plateau in the vicinity of Jean's Glade. The Western Allegheny Plateau has local relief, elevation, and forest density much greater than in the Interior Plateaus (Woods et al. 2002).

Geology

The Knobs-Lower Sciota Dissected Plateau is overlain by a mixture of capstone Pennsylvanian-age strata shale, siltstone, sandstone, and conglomerate at higher knob elevations and Silurian-age shale and dolomite at lower elevations (Peterson 1981; Noger 1988; Woods et al. 2002).

Sedimentary rock outcrops are commonly present in nearly all geologic systems of the Western Allegheny Plateau (Woods et al. 2002).

The mapped geology of the immediate surroundings of Jean's Glade is the Crab Orchard and Brassfield Dolomite Formations of the Lower and Middle Silurian System (Weir et al. 1971; Peterson 1981). The Crab Orchard Formation comprises greenish-gray clay shale and minor dolomite 12 to 18 m thick to the base. Weir et al. (1971) reported Crab Orchard shale and dolomite to be the thickest at Stillwater Branch, the second-order stream abutting Jean's Glade. This formation lies concordantly over the 3 to 6 m thick olive-green to yellowish-green dolomite of the Brassfield Dolomite Formation (Weir et al. 1971; Peterson 1981).

Soils

The general soil map unit for Madison County in the environs of Jean's Glade belongs to the Colyer-Weikert-Captina Soil Association (Newton et al. 1973). Soils of this association are shallow, poorly to moderately well drained, and occur along near level floodplains to lower hillside slopes within the Knobs Region (Newton et al. 1973). The two soils series at Jean's Glade are Newark silt loam and Shrouts silty clay loam (Newton et al. 1973; Soil Survey Staff 2017).

Newark silt loam, the principal soil series of Jean's Glade, is present on a nearly level alluvial floodplain of Stillwater Branch. Newark series on 0 to 4 percent slopes are somewhat poorly drained alluvial soils washed from limestone, shale, and siltstone; they are often flooded in the wet winter and early spring when the seasonal water table is 15 to 46 cm (Newton et al. 1973). A dark grayish-brown silt loam about 40 cm deep, Newark series is moderately permeable with high moisture capacity, very slow surface runoff, medium organic matter content, and a soil reaction pH near neutral (6.6 to 7.3) throughout the solum (Newton et al. 1973). Newark silt loam is the only soil of this series mapped in Madison County by Newton et al. (1973). At Jean's Glade, Newark silt loam is intermingled with Shrouts silty clay loam on the lower rocky slope of the *Juniperus-Quercus-Fraxinus-Ulmus-Cercis* Forest Edge.

Shrouts silty clay loam is severely eroded residuum from calcareous clay shale and brown-colored dolomite on hillsides of V-shaped valleys in the Knobs Region (Newton et al. 1973). This series consists of neutral to slightly alkaline, well-drained soils with a solum only 20 to 40 cm thick and a shallow root zone. Shrouts series occupy foot slopes from 6 to 12 percent to moderately steep 12 to 30 percent lower slopes (Newton et al. 1973). Available moisture capacity is low to very low or droughty within the root zone due to a slowly permeable clay layer. The depth to brown Silurian bedrock is 1.5 to 2.1 m with surface rock outcrops common. Vegetation with stands of *Juniperus virginiana* are characteristic of Shrouts clay series (Newton et al. 1973; Woods et al. 2002).

The neutral to mildly alkaline pH of the Newark soil series at Jean's Gentian Glade was confirmed through two separate soil sample analyses. Soil samples taken at five different locations within the glade macroplot revealed pH ranges from 6.7 to 7.4 with a mean of 7.2 (Sears 2014). An earlier pH analysis from a single Newark soil sample was a neutral-mildly alkaline 7.35. The soil texture was 21% sand, 53% silt, and 26% clay (Thom 2006). These two soil reports indicated high levels of potassium, magnesium, and calcium with low phosphorus. Thom (2006) reported the high calcium and magnesium values are related to the soil water above 7.0 pH. He stated potassium levels are most likely so high due to the large amount of dead *Juniperus virginiana* leaves on the soil surface where the nutrient readily leaches into the soil during rainfall. Thom (2006) concluded that "... the shallow soil depth indicates the present soil was formed from and remains heavily influenced by the underlying rock." This is especially relevant due to the significant number of species recorded in the macroplot that grow preferentially, or exclusively, in neutral to mildly alkaline calcareous soils.

Vegetation

The pre-settlement vegetation of the Knobs Region contained elements of the Mixed Mesophytic Forest and more so, the Western Mesophytic Forest, a transition of Oak-Hickory and Mixed Mesophytic Forest (Braun 1950). Forest resources in the Knobs Region have been utilized for lumber and charcoal since settlement in the late 1700s. Forest removal was most extensive during the period between 1808 and 1875 with only remnants of the original vegetation occupying steeper landscapes (Burroughs 1926). The distribution of species is strongly influenced by the parent material and soil/site conditions within the Knobs Region (Braun 1950, 1955). In strong contrast to the Pennsylvanian Allegheny Plateau to the east and Ordovician Bluegrass to the west, a portion of the Knobs Region is underlain by Silurian calcareous limestone strata that develop into limestone soils (Braun 1950; Peterson 1981).

Küchler (1964) described the potential vegetation in this region of Kentucky as *Quercus-Carya* Forest. The upland forested Knobs Region today predominately consist of *Quercus* and *Quercus-Pinus* vegetation. Forest vegetation on calcareous upland knob slopes includes *Quercus-Fraxinus* stands with a common *Juniperus virginiana* component (Woods et al. 2002). Muller and McComb (1986) studied eight upland forest sites in the Eastern and Western Knobs Region. They recognized Mesophytic Hardwood plots comparable to the Mixed Mesophytic Forests of the Cumberland Plateau of Braun (1950), which were readily separated from *Quercus alba*, *Q. coccinea*, and *Q. montana* plot sites. Important mesophytic hardwoods included *Acer rubrum*, *A. saccharum*, *Fagus grandifolia*, *Fraxinus americana*, *Liriodendron tulipifera*, *Quercus alba*, *Q. montana*, *Q. rubra*, and *Sassafras albidum* (Muller & McComb 1986). Jones and Thompson (1986) reported similar canopy tree composition, except for the absence of *Tsuga canadensis*, from a beech-hemlock stand in the Knobstone Escarpment (Knobs Region of Quarterman and Powell 1978) in extreme southeastern Madison County, ca. 11.0 km southeast of Jean's Glade.

In the Knobs Border Area east of the Kentucky Bluegrass section, isolated prairie inclusions (prairie relics) originally were surrounded by mesic forest types (Braun 1950, 1955). Where limestone was the underlying rock, the dominant species of the secondary forest communities were *Juniperus virginiana* and *Cercis canadensis* (Braun 1950). These relic prairie communities and scattered prairie species occurred along bands of Silurian dolomite and limestone outcrops in the Knobs Border Area (Braun 1950, 1955). Jean's Glade is an excellent example of a relict prairie inclusion habitat adjoining a subxeric mixed hardwood-red cedar forest edge.

Climate

Kentucky precipitation generally is distributed throughout the year although droughts may occur during hot, humid summers. Mildly cold winter temperatures are often are accompanied by minor snowfall (Trewartha & Horn 1980). Data from the Lexington Airport (1981–2010) report the mean annual precipitation (115 cm), lowest in January and February (8 cm), highest in May (13 cm), and a mean annual snowfall (33 cm). Mean annual temperature is 13.1° C with the coldest in January (3.3° C) and warmest in July (25.6° C). Median length of the growing season is 195 days above the base 0° C (MRCC 2017).

METHODS

A floristic study of vascular plants was made at Jean's Glade during August 2013 through October 2014 and April to September 2017 within a 0.11 ha (1100 m^2) measured macroplot. Thirty (1 m^2) quadrats were non-randomly placed to include the presence of a gentian genet to determine absolute frequency within the macroplot. Relative frequency, the number of quadrats with a species divided by 30 quadrats x 100 converted to a percentage, is a measure of abundance, distribution, and probability of a species' occurrence. Each taxon within the macroplot was given a locally inclusive relative abundance value following Thompson et al. (2012): R (Rare)–1 to 4 plants or genets; S

(Scarce)–5 to 10 plants or genets; I (Infrequent)–11 to 30 plants or genets; O (Occasional)–31 to 100 plants or genets; F (Frequent)–101 to 1000 plants or genets; and A (Abundant)–greater than 1000 plants or genets. Plant habitats were determined through field reconnaissance and sampling data of characteristic and dominant species in conjunction with physical site factors (geology, soils, topography, slope aspect, temperature-moisture regimes, and physiognomy). Species within the macroplot were documented with a representative voucher and deposited in the Ralph L. Thompson Berea College Herbarium (BEREA).

The percent foliar cover of 268 gentians within the macroplot was estimated visually. To determine gentian cover, 100 (1 m^2) quadrats were non-randomly placed along six transects to account for all 268 genets in the population and their respective ramets, when present.

Gentian ramets were non-randomly selected and their heights measured under three insolation conditions: full sun (mesic meadow), partial shade (near the tree line of the adjacent forest edge), and full shade (within the forest edge overstory boundary). Twenty ramets were selected for both full sun and partial shade areas. Only fifteen ramets for the full shade area were available for measurement. Non-flowering ramets were measured, using a meter stick, from the ground to the apex of the stem and an average was determined for each group. Plants were measured during the first week of August 2015, approximately one month before they began to produce flowers.

Manuals for identification or verification of taxa are Jones (2005), Tennessee Flora Committee (2015), and Weakley (2015). Nomenclature is established by the Tennessee Flora Committee (2015) except for a few taxa from USDA, NCRS (2017). Clade sections are from Weakley (2015). Non-native invasive status is determined by KY-EPPC (2013).

RESULTS AND DISCUSSION

Three major plant habitats are designated within the 0.11 ha macroplot and described with associated species in conjunction with Appendix 1 (Quadrat Frequency), Appendix 2 (Species List), and Table 1 (Taxonomic Summary). Quantitative data are examined from quadrat sampling, relative abundance, gentian foliar cover, gentian height, and a floristic summary.

Wetland sedge-rush ground seep

A permanently saturated area of alluvial Newark silt loam soils, where it is too wet for gentians to grow, is located at the extreme southwestern edge of the macroplot contiguous to an entranceway gravel road. This alluvial floodplain habitat is subjected to annual winter and spring floods from Stillwater Branch. Wetland graminoid associates include taxa of the Cyperaceae, *Carex frankii*, *C. lurida*, *C. vulpinoidea*, *Cyperus flavescens*, *Scirpus atrovirens*, and *S. pendulus*, the Juncaceae, *Juncus acuminatus*, *J. dudleyi*, *J. effusus* subsp. *solutus*, and *J. torreyi*, and Poaceae, *Dichanthelium polyanthes*, *Glyceria striata*, and two annual Asian invasives, *Arthraxon hispidus* and *Microstegium vimineum*. Characteristic wetland dicot species are *Agrimonia rostellata*, *Amphicarpaea bracteata*, *Bidens polylepis*, *Conoclinum coelestinum*, *Eupatorium perfoliatum*, *Eutrochium fistulosum*, *Impatiens capensis*, *Lobelia siphilitica*, *Ludwigia alternifolia*, *Lycopus virginicus*, *Mimulus alatus*, *Salvia lyrata*, and *Samolus parviflorus*. *Salix nigra* and *Sambucus canadensis* are indicator woody species. Facultative and obligate wetland plants are generally restricted to this ground seep habitat (Appendix 1, 2).

Mesic prairie inclusion meadow

Robison et al. (1995) described the mesic prairie community, soils, and indicator plants in the North Central states (Indiana, Iowa, Minnesota, Missouri, Nebraska, Ohio). In those states, *Gentiana flavida* is characterized as "competition sensitive," i.e., it is not able to compete (shade intolerant) and declines or dies out among competition from native weedy and alien (exotic) species. Mesic prairie sites typically have surface drainage where water does not collect in the loam soils (Robison et al.

1995). We classify the largest habitat where approximately 72% of the *Gentiana flavida* population is found as the mesic prairie inclusion meadow (Figure 1, 3). At Jean's Glade, several prairie remnants or prairie relics inhabiting the mesic prairie inclusion meadow are characteristic of Kentucky and North Central states mesic prairies.

Throughout the mesic prairie inclusion meadow, Newark silt loam soils intergrade into Shrouts silt clays of the hardwood-red cedar forest edge habitat. Several prairie taxa grow among characteristic old-field and disturbed sites. The mesic meadow transitions into the wetland seep habitat on the near level floodplain below and above into the subxeric rocky outcrop of the mixed hardwoods-red cedar forest edge lower slope. The meadow has numerous rocky woodland taxa interspersed by varying frequency and relative abundance.

Several mesic tallgrass prairie taxa are scattered throughout this meadow habitat. Moreover, most of these prairie remnants have a low frequency within the 1 m^2 quadrats (Appendix 1) and are rare, scarce, or infrequent in relative abundance in the macroplot (Appendix 2). Within the gentian macroplot, characteristic prairie species of moist calcareous meadows, glades, and barrens include *Asclepias tuberosa*, *A. verticillata*, *Astranthium integrifolium*, *Carex granularis*, *Chamaecrista fasciculata*, *Echinacea purpurea*, *Eryngium yuccifolium*, *Eupatorium altissimum*, *Euphorbia corollata*, *Fragaria virginiana*, *Gaura biennis*, *Gentianella quinquefolia*, *Lithospermum canescens*, *Lobelia siphilitica*, *L. spicata*, *Manfreda virginica*, *Matelea obliqua*, *Monarda fistulosa*, *Phlox glaberrima*, *Physostegia virginiana*, *Ratibida pinnata*, *Rudbeckia hirta*, *Schizachyrium scoparium*, *Silphium trifoliatum*, *Thalictrum revolutum*, and *Zizia aurea* (Appendix 2).

Many mesic to subxeric taxa characteristic of old-field colonizers exhibit a weedy habit in the meadow. Characteristic native weedy taxa include *Agrimonia rostellata*, *Ambrosia artemisiifolia*, *Calystegia sepium*, *Carex hirsutella*, *Conoclinum coelestinum*, *Desmodium glabellum*, *D. paniculatum*, *Dichanthelium clandestinum*, *Erigeron philadelphicus*, *Geum canadense*, *Leersia virginiana*, *Lysimachia lanceolata*, *Muhlenbergia sylvatica*, *Panicum anceps*, *Potentilla simplex*, *Sisyrinchium angustifolium*, *Solidago altissima*, *S. nemoralis*, *Symphotrichum shorti*, *S. pilosum*, *Tridens flavus*, *Verbesina alternifolia*, and *Vernonia gigantea*. *Rubus argutus* and *R. flagellaris* are interspersed throughout the meadow (Appendix 1, 2). The gentian population is in danger from the severe-threat invasives *Arthraxon hispidus*, *Microstegium vimineum*, and *Schedenorus arundinaceus*. Other severe-threat or significant-threat invasive taxa are *Celastrus orbiculatus*, *Daucus carota*, *Dioscorea polystachya*, *Glechoma hederacea*, *Lonicera japonica*, *Melilotus alba*, *M. officinalis*, and *Poa compressa*. Smith (1994) noted that the greatest non-native threat to *Gentiana flavida* in Arkansas was loss of habitat due to invasive cool-season grasses, especially *Schedonorus arundinaceus*.

In the moist prairie inclusion meadow, many woody plants with notable relative frequency are volunteering from the subxeric mixed hardwood-red cedar rocky forest edge even with current seasonal maintenance of cutting back shrubs and tree saplings. Woody vines, *Campsis radicans*, *Lonicera japonica*, *Parthenocissus quinquefolia*, *Toxicodendron radicans*, and shrubs, *Corylus americana*, *Rhamnus caroliniana*, *Rhus aromatica*, *Rosa carolina*, *R. setigera*, and *Viburnum rufidulum*, are important colonizers. Native tree seedlings and saplings established in the prairie inclusion meadow include *Acer saccharum*, *Carpinus caroliniana*, *Carya ovata*, *Celtis occidentalis*, *Cercis canadensis*, *Cornus florida*, *Fagus grandifolia*, *Fraxinus americana*, *F. quadrangulata*, *Juniperus virginiana*, *Liriodendron tulipifera*, *Pinus virginiana*, *Quercus alba*, *Q. imbricaria*, *Q. muhlenbergii*, *Q. rubra*, and *Robinia pseudoacacia* (Appendix 1, 2). The gentian population remains in severe jeopardy due to the continuous encroachment of the woody taxa shading out existing individuals in the absence of fire.

Subxeric mixed hardwood-red cedar forest edge

The mixed hardwood-red cedar forest edge is composed of Shrouts calcareous silt clay soils with Silurian shale and dolomite outcrops on a southwest-trending rocky lower slope. Numerous herbs and woody plants that thrive on calcareous substrates are established with soil moisture conditions varying from mesic to subxeric (Figure 1). *Gentiana flavida* occupies about 28% of the forest edge. The highest species richness is present in the forest edge stand as it is actively encroaches into the moist gentian prairie inclusion meadow.

The largely shaded moist-dry or subxeric habitat is the only location for four rare to scarce ferns, *Asplenium platyneuron*, *Botrypus virginianus*, *Polystichum acrostichoides*, and *Sceptridium dissectum*, and a rare orchid, *Spiranthes tuberosa*. Native perennial herbs among the dolomitic shale outcrops include *Agrostis perennans*, *Allium cernuum*, *Anemone virginiana*, *Arnoglossum atriplicifolium*, *Bromus pubescens*, *Carex amphibola*, *C. blanda*, *C. willdenowii*, *Cunila origanoides*, *Dichanthelium bosci*, *D. commutatum*, *Elymus hystrix*, *Endodeca serpentaria*, *Erigeron pulchellus*, *Galium circaezans*, *Helianthus microcephalus*, *Houstonia canadensis*, *Lespedeza repens*, *Lysimachia quadrifolia*, *Packera obovata*, *Penstemon digitalis*, *Podophyllum peltatum*, *Rudbeckia fulgida*, *R. triloba*, *Sanicula odorata*, *Scutellaria nervosa*, *Solidago caesia*, *Smallanthus uvedalius*, *Symphotrichum patens*, *Thaspium chapmanii*, *Uvularia perfoliata*, and *Viola hirsutula* (Appendix 2). Non-native or exotic naturalized and invasive species in the forest edge are typically those found in the mixed prairie inclusion meadow.

The subxeric mixed hardwood-red cedar forest edge comprises the woody vines, shrubs, subcanopy and canopy trees in the forested environs of Jean's Glade. Native indicator calciphile trees in Shrouts and integrading Newark silt loams include *Acer saccharum*, *Carya ovata*, *Celtis occidentalis*, *C. tenuifolia*, *Cercis canadensis*, *Fraxinus americana*, *F. quadrangulata*, *Juglans nigra*, *Juniperus virginana*, *Prunus serotina*, *Quercus muhlenbergii*, *Robinia pseudoacacia*, and *Ulmus americana*. Other important subcanopy and canopy trees are *Carpinus caroliniana*, *Carya cordiformis*, *Cornus florida*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Ostrya virginiana*, *Pinus virginiana*, *Quercus alba*, *Q. rubra*, *Q. velutina*, and *Ulmus rubra*. Woodland shrubs are *Corylus americana*, *Lindera benzoin*, *Rhamnus carolinana*, *Rhus aromatica*, *Rosa carolina*, and *Viburnum rufidulum*. Important native lianas are *Campsis radicans*, *Parthenocissus quinquefolia*, *Smilax bona-nox*, *Toxicodendron radicans*, and *Vitis aestivalis*.

Braun (1950) recorded *Juniperus virginiana* and *Cercis canadensis* as dominant tree species of limestone secondary forest communities where relic prairie species were present. Rhoades et al. (2005) reported soils, habitat types, and woody plant composition in forest vegetation across grass and forb glade-forest ecotones of the Crooked Creek Barrens State Nature Preserve, in Lewis County, Kentucky. The Preserve has calcareous soils from Silurian shale and dolomite of the Crab Orchard Formation, and is located in the extreme Western Allegheny Plateau of Woods et al. (2002). *Juniperus virginiana* had the highest density within the glade interior and glade edges and was important in the forest edge and forest interior. *Cercis canadensis* and *Fraxinus americana* were first and third in density of the forest edge, and *Fraxinus americana* and *Cercis canadensis* had the highest density in the forest interior (Rhoades et al. 2005). Rhoades et al. (2005) also concluded that the locally rare prairie plants of this Preserve were threatened by land conversion, land degradation, woody plant encroachment, and non-native invasives. Jean's Glade has similar calcareous soils of the Silurian System Crab Orchard Formation within the Western Allegheny Plateau, non-native invasives, and also comprises a comparable *Juniperus-Quercus-Fraxinus-Ulmus-Cercis* forest association to Crooked Creek Barrens State Nature Preserve.

Relative frequency

A total of 143 species, representing 28 families, were present within the 30 quadrats (Appendix 1), comprising 67.77% of the total species present in the macroplot. An additional 68

species occurred within the macroplot boundary but not in quadrats. *Toxicodendron radicans, Amphicarpaea bracteata*, *Microstegium vimineum*, *Desmodium paniculatum*, *Parthenocissus quinquefolia*, *Schedonorus arundinaceus*, *Thalictrum revolutum*, *Fragaria virginiana*, and *Lonicera japonica*, had a relative frequency of 40% or greater. Seventeen species had a relative frequency of at least 30%, 33 species at least 20%, and 63 species at least 10% relative frequency (Appendix 1). An additional 89 species were recorded with less than 10% relative frequency.

Relative abundance

Within the macroplot, only three invasive grasses, *Arthraxon hispidus*, *Microstegium vimineum*, and *Schedonorus arundinaceus* were Abundant (A) in relative abundance (Appendix 2). The lack of additional species in this category, however, is not surprising considering the relatively small area of the macroplot. A total of 73 species (34.59% of recorded species) were either Occasional (O) or Frequent (F). Of the species in these two categories, there were two gymnosperms, one primitive angiosperm, 19 monocots, and 51 dicots. For species recorded as O or F, 62 occurred in the 1 m^2 quadrats (Appendix 2). Twenty-five species were recorded as being Rare (R): two ferns, six monocot, and 17 dicot species. No species with an R designation occurred in more than one of the 30 (1 m^2) quadrats. Sixty-eight species (32.23% of recorded species) identified in the macroplot did not appear in any of the individual quadrats. This inconsistent data is a result of the sampling timeframes. The macroplot vascular plant survey accounted for species present during all seasons of growth from spring through autumn. The 30 (1 m^2) quadrat survey, however, took place during autumn of September 2013, when the gentian population was at its flowering peak. Thus, a number of the spring and summer species present in the macroplot would have not been observed in the quadrats as they had already undergone senescence and disappeared.

Percent foliar cover

Gentians were present in 47 of the 100 (1 m^2) non-random quadrats within the macroplot. Of these quadrats, only five were represented by more than 15% gentian foliar coverage (plots that contained genets with several ramets). The majority of quadrats represented very low coverage as 30 out of 47 contained less than 5% foliar coverage. For the quadrats with gentians present, the species represented a mean foliar coverage of only 8.18%; this data concurs with other observations. Wood and Weaver (1982) reported native *Gentiana* species are never a dominant species in the various plant communities that they inhabit.

Insolation effects on plant height

The effects of full sun, partial shade, and canopy shade on gentian height have been observed in the field (Pringle 1963; Hilty 2008; Bebeau 2014). A total of 55 ramets were measured for height under full sun, partial shade, and total canopy shade. Plants in full sun reached an average height of 73.09 cm, those in partial shade, 56.68 cm, and those under full shade, 43.28 cm. Plants under full shade did not grow as tall as those that were not shaded at all, differing by over 30 cm in average height. In 2016, three of the 15 ramets measured in 2015 under total shade could not be located and, most likely, had perished. Genets of all ramets measured in full sun or partial shade in 2015 were relocated in 2016. Moreover, cream gentians do not thrive as well under total shaded areas compared to partial shade or full sun conditions. Leaf colors were dark green in shaded habitats, olive-green in full sun, and greenish-yellow when strongly bleached by the sun. These observations follow those reports by Hilty (2008) and Bebeau (2014).

Floristic summary

The vascular plants of Jean's Glade comprise 211 species in 156 genera from 69 families (Table 1). Clade sections consist of four ferns, two gymnosperms, three magnoliids, 46 monocots, and 156 dicots (Table 1). Nineteen non-native naturalized taxa are present with 16 severe-threat or significant-threat invasives. A total of 161 are herbaceous (38 graminoids and 123 forbs) and 50 are woody (33 trees, 5 shrubs, and 12 lianas). The largest families in species are Asteraceae (36),

Poaceae (22), Cyperaceae, and Fabaceae (12 each). Sixteen invasive taxa comprise 7.58% of the 211 species. Invasive grasses, *Arthraxon hispidus*, *Microstegium vimineum*, and *Schedonorus arundinaceus*, are the most severe-threat taxa. *Celastrus orbiculatus*, *Dioscorea polystachya*, *Glechoma hederacea*, and *Lonicera japonica*, are also important severe-threat species (Appendix 1, 2).

Table 1. Taxonomic distribution of vascular plants of Jean's Glade, Madison Co., Kentucky.

Clade	Family	Genera	Species	Native	Non-native	Invasive	Species %
Ferns	3	4	4	4	0	0	1.90
Gymnosperms	2	2	2	2	0	0	0.95
Magnoliids	3	3	3	3	0	0	1.42
Monocots	11	28	46	40	6	5	21.80
Dicots	50	119	156	143	13	11	73.93
Total:	69	156	211	192	19	16	100.00

CONCLUSIONS

A qualitative and quantitative ecological study of the gentian population emphasized relative frequency, relative abundance, gentian foliar cover, gentian height, and a comprehensive vascular plant survey.

1. Jean's Glade has a stable, healthy population of 268 gentian genets, many with several ramets, that occur within two habitats: (a) an open, highly insolated Mesic Prairie Inclusion Meadow and (b) a rocky lower slope at a Subxeric Mixed Hardwood-Red Cedar Forest Edge.

2. The vascular flora of Jean's Glade has significantly high species richness for a small 0.11 ha site (59 families, 156 genera, and 211 specific and infraspecific taxa). The 211 species represents 8.12% of the total 2600 species that Jones (2005) listed for Kentucky. Nineteen non-native species are documented; three are naturalized while 16 are severe-threat or significant-threat invasives. Vascular species include 161 herbaceous (38 graminoids and 123 forbs) and 50 woody (33 trees, 5 shrubs, and 12 lianas).

3. Cream gentians exhibited low foliage coverage with a mean of 8.18 percent for genets and their corresponding ramets. Gentian height measurements under various insolation revealed greater plant height under full sun, a lesser height under partial shade, and the least height and survival under total overstory shade. Data indicate a shade-intolerant or competition-sensitive taxon adapted to open, sunny habitats, i.e., mesic prairie inclusion meadow.

4. Physical and biological parameters are strongly associated with the presence of Jean's Glade gentian population and prairie species: Silurian dolomite and shale substrate, calcareous neutral to mildly alkaline (mean 7.20–7.35 pH). Newman and Shrouts soils, essential temperature-moisture regimes, and the calciphile indicator prairie remnants.

5. This gentian population compellingly merits preservation due to its endangered status in Kentucky. Three major concerns exist regarding the continuation of a healthy gentian population and survival of the other indicator mesic prairie remnants: (a) the advent and spread of severe-threat and significant-threat exotic invasive taxa; (b) management and control of woody plants encroachment from the forest edge by cutting and use of fire; and (c) an actual danger of future herbicide-spraying along a powerline corridor that passes directly through the macroplot.

6. The cream gentian population in Madison County appears to be similar to four Kentucky county populations (Lewis, Nicholas, Rowan, Robertson) where gentians have been reported from past observations by the KSNPC (2017). Our comparative inference is largely based on sparse occurrence record literature, without voucher specimens, and a meager few herbarium specimens documented to date. Similar physical and biological parameters exist in these five populations, all of which are situated within the Outer Bluegrass, Inner Bluegrass, and Hills of the Bluegrass Ecoregions of the Interior Plateau, or the Knobs Region of the Western Allegheny Plateau of Woods et al. (2002).

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LITERATURE CITED

Andreas, B.A. and T.S. Cooperrider. 1981. The Gentianaceae and Menyanthaceae of Ohio. Castanea 46: 102–108.

Bebeau, E.D. 2014. Plants of the Eloise Butler Wildflower Garden: Plains Gentian (*Gentiana alba* Muhl. ex Nutt). The Friends of the Wild Flower Garden, Inc. <http://www.friendsofthewildflowergarden.org/pages/plants/plaingentian >

Bowles, J.M. and C.R. Jacobs. 2010. COSEWIC assessment and update status report on the white prairie gentian *Gentiana alba* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Braun, E.L. 1950. Deciduous Forests of Eastern North America. Hafner Press, Macmillan Publishing Co., New York.

Braun, E.L. 1955. Phytogeography of unglaciated eastern United States. Bot. Rev. 21: 297–375.

Burroughs, W.G. 1926. Geography of the Kentucky Knobs. Kentucky Geological Survey, Series 6, 19: 1–211, Frankfort, Kentucky.

Campbell, J. 2003. Ecoregional sections of Kentucky: Derived from soil associations mapped by USDA (STATSGO); with modification also based on geology, topography, vegetation, and biogeography (map scale: 1:333,333). The Nature Conservancy, Lexington, Kentucky.

Campbell, J. and M. Medley. 2012. The Atlas of Vascular Plants in Kentucky. Draft of July 2012, with provisional listing of authors: Atlas introduction and exclamation. <https://www.bluegrasswoodland.com >

Fenneman, N.M. 1938. Physiography of the Eastern United States. McGraw-Hill Book Co., Inc., New York.

Gray, A. and W.S. Sullivant. 1846. Musci Alleghanienses, sive Spicilegia Muscorum atque Hepaticurum quos in itinere a Marylandia usque ad Georgiam per tractus montium A.D. MDCCCXLIII. Amer. J. Science, Ser. 2, 1: 80.

Heikens, A.L. 2002. Conservation assessment for yellowish gentian (*Gentiana alba*). USDA Forest Service. Eastern Region, Hoosier National Forest, Milwaukee, Wisconsin.

Hilty, J. 2008. Wildflowers of Illinois in Savannahs and Thickets. <http://www.illinoiswildflowers.info/savannah/plants/cr_gentian.htm >

Jones, R.L. 2005. Plant life of Kentucky: An Illustrated Guide to the Vascular Flora. Univ. Press of Kentucky, Lexington.

Jones, R.L. and R.L. Thompson. 1986. A beech-hemlock stand in the Knobstone Escarpment of Madison County, Kentucky. Trans. Kentucky Acad. Sci. 47: 101–105.

Kartesz, J.T. 2015. The Biota of North America Program (BONAP). North American Plant Atlas. Chapel Hill, North Carolina [maps generated from Kartesz, J.T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP)]. <http://bonap.net/mapgallery/state/Gentiana alba.png >

KSNPC (Kentucky State Nature Preserves Commission). 2017. Kentucky State Nature Preserves Commission, Rare Plants: Yellow Gentian (*Gentiana flavida*). <http://eppcapp.ky.gov/nprareplants/ >

Küchler, A.W. 1964. Manual to accompany the map of potential natural vegetation of the conterminous United States (map scale: 1:3,168,000). Amer. Geogr. Soc. Spec. Bull. 36. New York.

KY-EPPC (Kentucky Exotic Plant Pest Council). 2013. Kentucky Exotic Plant Pest Council invasive exotic plant list. <http://www.se-eppc.org/ky/list.htm >

McFarlan, A.C. 1943. Geology of Kentucky. The Univ. of Kentucky, Lexington.

Medley, M.E. 1993. An annotated catalog of the known or reported vascular flora of Kentucky. Ph.D. dissertation, Univ. of Louisville. Louisville, Kentucky.

MRCC (Midwest Regional Climate Center). 2017. Climate of the Midwest: Kentucky: Station USW00093820-Lexington Bluegrass Airport. <http://mrcc.isws.illinois.edu.mw_climatesummaries/climateSummary_station_ USW00093820-Lexington_Bluegrass_Ap. >

Muhlenberg, G.H.E. 1813. Catalogue Plantarum Americae Septentrionalis, No. 29.

Muller, R.N. and W.C. McComb. 1986. Upland forests of the Knobs Region of Kentucky. Bull. Torrey Bot. Club 113: 268–280.

NatureServe. 2017. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. <http://explorer.natureserve.org >

Newell, W.L. 1981. Contributions to the geology of Kentucky: Physiography. In: R.C. McDowell (ed.). The Geology of Kentucky—A Text to Accompany the Geologic Map of Kentucky. U.S. Geological Survey, Professional Paper 1151-H, Washington, D.C. <https://pubs.usgs.gov/pp/p1151h/physiography.html >

Newton, J.H., H.P. McDonald, D.G. Preston, A.J. Richardson, and R.P. Sims. 1973. Soil Survey of Madison County, Kentucky. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

Noger, M.C. (comp.). 1988. Geologic Map of Kentucky. Sesquicentennial edition of the Kentucky Geological Survey, Series 11. (map scale: 1:500,000). Kentucky Geological Survey, Reston, Virginia.

Nuttall, T. 1818. The Genera of North American Plants, and a catalogue of the species, to the year 1817. Published by the author, Philadelphia, Pennsylvania.

Peterson, W.L. 1981. Contributions to the geology of Kentucky: Silurian System. In: R.C. McDowell (ed.). The Geology of Kentucky— A Text to Accompany the Geologic Map of Kentucky. U.S. Geological Survey, Professional Paper 1151-H, Washington, D.C. <https://pubs.usgs.gov/pp/p1151h/silurian.html >

Pringle, J.S. 1963. A systematic study of the section *Pneumonanthae* of *Gentiana* in eastern North America. Ph.D. dissertation, Univ. of Tennessee, Knoxville.

Pringle, J.S. 1965. The white gentian of the prairies. Michigan Bot. 4: 43–47.

Pringle, J.S. 1967. Taxonomy of *Gentiana*, section *Pneumonanthe*, in eastern North America. Brittonia 19: 1–32.

Pringle, J.S. 2017. *Gentianaceae*. Flora of North America Editorial Committee, Vol. 14. Provisional Treatment (In review). St. Louis, Missouri.

Quarterman, E. and R.L. Powell. 1978. Potential Ecological/Geological Natural Landmarks on the Interior Low Plateau. U.S. Department of the Interior, Washington, D.C.

Rhoades, C.C., S.P. Miller, and D.L. Skinner. 2005. Forest vegetation and soil patterns across glade-forest ecotones in the Knobs Region of northeastern Kentucky, USA. Amer. Midl. Naturalist 154: 1–10.

Robison, R., D.B. White, and M.H. Meyer. 1995. Plants in Prairie Communities. Univ. of Minnesota Extension Service, North Central Regional Extension Publication AG-FO-3238-C. University of Minnesota Digital Conservancy, St. Paul, Minnesota <http://hdl.handle.net/11299/93930 >

Sears, A. 2014. Soil samples analyses from Jean's Glade, Madison County. Univ. of Kentucky Cooperative Extension Service, College of Agriculture, Lexington.

Smith, E.B. 1994. Keys to the flora of Arkansas. Univ. of Arkansas Press, Fayetteville.

Soil Survey Staff. 2017. Natural Resources Conservation Service, United States Department of Agriculture. 2017. Soils survey of Madison County, Kentucky, Sheet 31. Web Soil Survey. <https://websoilsurvey.sc.egovusda.gov/ >

Steyermark, J.A. 1963. Flora of Missouri. Iowa State Univ. Press, Ames.

Tennessee Flora Committee. 2015. Guide to the Vascular Plants of Tennessee. E.W. Chester, B.E. Wofford, J. Shaw, D. Estes, and D.H. Webb (eds.). The Univ. of Tennessee Press, Knoxville.

Thom, W.O. 2006. Soil analysis from Jean's Glade, Madison County. Univ. of Kentucky Cooperative Extension Service, College of Agriculture, Lexington.

Thompson, R.L., D.B. Poindexter, and J.R. Abbott. 2012. Vascular flora and plant communities of Dead Horse Knob (Rucker's Knob), Madison County, Kentucky. J. Bot. Res. Inst. Texas 6: 631–651.

Trewartha, G.T and L.H. Horn. 1980. An Introduction to Climate (ed. 5). McGraw-Hill Book Company, New York.

USDA, NRCS (United States Department of Agriculture, National Resources Conservation Service). 2017. The PLANTS Database < http://plants.usda.gov >. National Plant Data Center, Greensboro, North Carolina.

Waldron, G.E. 2001. Update COSEWIC status report on the white prairie gentian *Gentiana alba* in Canada. In: COSEWIC assessment and update status report on the white prairie gentian *Gentiana alba* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Weakley, A.S. 2015. Flora of the Southern and Mid-Atlantic States. Univ. of North Carolina Herbarium (NCU), North Carolina Botanical Garden, and UNC at Chapel Hill. <www.herbarium.unc.edu/FloraArchives/WeakleyFlora_2015-05-29.pdf >

Weir, G.W., K.Y. Lee, and P.E. Cassity. 1971. Geologic map of the Bighill Quadrangle East-Central Kentucky. Map GQ-900 (map scale: 1:24,000). Department of the Interior, U.S. Geological Survey, Washington, D.C.

Wilbur, R.L. 1988. The correct scientific name of the pale yellow or white gentian of the eastern United States. Sida 13: 161–165.

Wood, C.E. and R.E. Weaver, Jr. 1982. The genera of *Gentianaceae* in the southeastern United States. J. Arnold Arb. 63: 441–487.

Woods, A.J., J.M. Omernik, W.H. Martin, G.J. Pond, W.M. Andrews, S.M. Call, J.A. Comstock, and D.D. Taylor. 2002. Ecoregions of Kentucky (color poster with map, descriptive text, summary tables, and photographs (map scale: 1:250,000). U.S. Geological Survey, Reston, Virginia.

Yatskievych, G. 2013. Steyermark's Flora of Missouri. Vol. 3. Missouri Botanical Garden Press, St. Louis.

Appendix 1. Relative frequency from 30 (1 m^2) quadrats in Jean's Glade, Madison Co., Kentucky.

Family	Species	Absolute Frequency	Relative Frequency %
Gentianaceae	*Gentiana flavida*	30	100.00
Anacardiaceae	*Toxicodendron radicans*	22	73.33
Fabaceae	*Amphicarpaea bracteata*	17	56.67
Poaceae	******Microstegium vimineum*	16	53.33
Fabaceae	*Desmodium paniculatum*	15	50.00
Vitaceae	*Parthenocissus quinquefolia*	15	50.00
Poaceae	******Schedonorus arundinaceus*	14	46.67
Ranunculaceae	*Thalictrum revolutum*	13	43.33
Rosaceae	*Fragaria virginiana*	12	40.00
Caprifoliaceae	******Lonicera japonica*	12	40.00
Fabaceae	*Chamaecrista fasiculata*	11	36.67
Fabaceae	*Desmodium glabellum*	11	36.67
Asteraceae	*Solidago altissima*	11	36.67
Apiaceae	******Daucus carota*	10	33.33
Asteraceae	*Arnoglossum atriplicifolium*	9	30.00
Bignoniaceae	*Campsis radicans*	9	30.00
Oleaceae	*Fraxinus americana*	9	30.00
Rosaceae	*Agrimonia rostellata*	8	26.67
Convolvulaceae	*Calystegia sepium*	8	26.67
Fabaceae	*Cercis canadensis*	8	26.67
Poaceae	*Dichanthelium bosci*	8	26.67
Asclepiadaceae	*Matelea obliqua*	8	26.67
Apiaceae	*Sanicula odorata*	8	26.67
Rosaceae	*Geum canadense*	7	23.33
Pinaceae	*Pinus virginiana*	7	23.33
Rosaceae	*Potentilla simplex*	7	23.33
Fagaceae	*Quercus rubra*	7	23.33
Asteraceae	*Vernonia gigantea*	7	23.33
Poaceae	*Dichanthelium clandestinum*	6	20.00
Euphorbiaceae	*Euporbia corollata*	6	20.00
Asteraceae	*Packera obovata*	6	20.00
Lamiaceae	*****Prunella vulgaris*	6	20.00
Asteraceae	*Smallanthus uvedalius*	6	20.00
Cyperaceae	*Carex blanda*	5	16.67
Asteraceae	*Conoclinum coelestinum*	5	16.67
Cupressaceae	*Juniperus virginiana*	5	16.67
Fabaceae	*Lespedeza repens*	5	16.67
Boraginaceae	*Lithospermum canescens*	5	16.67
Ulmaceae	*Ulmus rubra*	5	16.67
Asteraceae	*Bidens polylepis*	4	13.33
Poaceae	*Elymus hystrix*	4	13.33
Asteraceae	*Eutrochium fistulosum*	4	13.33
Lamiaceae	******Glechoma hederacea*	4	13.33

Lamiaceae	*Scutellaria nervosa*	4	13.33
Iridaceae	*Sisyrinchium angustifolium*	4	13.33
Asteraceae	*Symphyotrichum pilosum*	4	13.33
Apiaceae	*Thaspium chapmanii*	4	13.33
Poaceae	***Arthraxon hispidus*	4	13.33
Rosaceae	*Agrimonia parviflora*	3	10.00
Asteraceae	*Astranthium integrifolium*	3	10.00
Cyperaceae	*Carex hirsutella*	3	10.00
Cornaceae	*Cornus florida*	3	10.00
Betulaceae	*Corylus americana*	3	10.00
Poaceae	*Dichanthelium commutatum*	3	10.00
Oleaceae	*Fraxinus quadrangulata*	3	10.00
Asteraceae	*Helianthus microcephalus*	3	10.00
Asteraceae	***Leucanthemum vulgare*	3	10.00
Campanulaceae	*Lobelia siphilitica*	3	10.00
Berberidaceae	*Podophyllum peltatum*	3	10.00
Rhamnaceae	*Rhamnus caroliniana*	3	10.00
Rosaceae	*Rosa carolina*	3	10.00
Asteraceae	*Solidago caesia*	3	10.00
Vitaceae	*Vitis aestivalis*	3	10.00

28 families, 143 species in 30 (1 m^2) quadrats; an additional 63 species are less than 10% frequency.

(*) Naturalized taxon; (**) Invasive pest plant taxon (KY-EPPC 2013)

Appendix 2. Vascular plants of Jean's Glade, Madison Co., Kentucky.

Family	Species	Absolute Frequency	Relative Abundance
	MONILOPHYTA (FERNS)		
ASPLENIACEAE			
	Asplenium playneuron (L.) B.S.P. *13-625*	-	S
DRYOPTERIDACEAE			
	Polystichum acrostichoides (Michx.) Schott *14-127*	-	S
OPHIOGLOSSACEAE			
	Botrypus virginianus (L.) Holub *14-123; 17-212*	-	R
	Sceptridium dissectum (Spreng.) Lyon *13-636*	1	R
	AGROGYMNOSPERMAE (EXTANT GYMNOSPERMS)		
CUPRESSACEAE			
	Juniperus virginiana L. *13-563*	5	O
PINACEAE			
	Pinus virginiana Mill. *13-540*	7	O
	MAGNOLIIDS AND PRIMITIVE ANGIOSPERMS		
ARISTOLOCHIACEAE			
	Endodeca serpentaria (L.) Raf. *13-491; 13-616*	1	S

LAURACEAE		
Lindera benzoin (L.) Blume *13-553*	1	I
MAGNOLIACEAE		
Liriodendron tulipifera L. *13-551*	-	O
MONOCOTYLEDONAE ANGIOSPERMS		
AGAVACEAE		
Manfreda virginica (L.) Salisb. ex Rose *13-639; 14-363*	-	R
ALLIACEAE		
Allium cernuum Roth *13-476; 14-564*	2	I
AMARYLLIDACEAE		
**Narcissus pseudonarcissus* L. *17-43*	-	S
COLCHICACAE		
Uvularia perfoliata L. *13-535*; *17-224*	-	S
CYPERACEAE		
Carex amphibola Steud. *14-162*	2	O
Carex blanda Dewey *14-152; 17-220*	5	O
Carex frankii Kunth *14-361*	-	S
Carex granularis Muhl. ex Willd. *14-180*	-	O
Carex hirsutella Mackenzie *14-207; 17-205*	3	O
Carex lurida Wahlenb. *14-158; 17-223*	-	O
Carex vulpinoidea Michx. *14-166*	-	O
Carex willdenowii Schkuhr. ex Willd. *14-156*	1	I
Cyperus flavescens L. *13-449; 17-483*	-	S
Cyperus strigosus L. *14-561*	-	R
Scirpus atrovirens Willd. *13-444; 14-226*	-	O
Scirpus pendulus Muhl. ex Elliott. *13-463; 14-228*	-	O
DIOSCOREACEAE		
***Dioscorea polystachya* Turcz. *13-537*	1	I
IRIDACEAE		
Sisyrinchium angustifolium Mill. *14-182*	4	I
JUNCACEAE		
Juncus acuminatus Michx. *14-227*	-	R
Juncus dudleyi Wiegand *14-230; 14-366*	-	O
Juncus effusus L. ssp. *solutus* (Fern. & Wieg.) Hämet-Ahti. *14-224*	-	O
Juncus torreyi Coville *13-448*	-	S
ORCHIDACEAE		
Spiranthes tuberosa Raf. *17-473*	-	R
POACEAE		
*Agrostis perennan*s (Walt.) Tuckerman *14-568*	-	S
***Arthraxon hispidus* (Thunb.) Makino *14-566*	4	A
Bromus pubescens Muhl. ex Willd. *14-206*	1	I
Danthonia spicata (L.) P. Beauv. ex Roemer & Schultes *17-214*	4	O
Dichanthelium bosci (Poir.) Gould & Clark. *13-516*	8	O
Dichanthelium acuminatum (Sw.) Gould & Clark *17-222*	-	I
Dichanthelium clandestinum (L.) Gould *13-524*	6	O
Dichanthelium commutatum (Schultes) Gould *14-144*	3	I
Dichanthelium polyanthes (Schultes) Mohlenbrock *14-365*	-	R
Elymus hystrix L. *14-225*	4	O
Elymus macgregori Brooks & Campbell *14-364*	-	R
Glyceria striata (Lam.) Hitchc. *14-173*	2	I
Leersia virginica Willd. *13-513*	2	O

***Microstegium vimineum* (Trin.) A. Camus *13-626*	16	A
Muhlenbergia sylvatica (Torr.) Torr. ex A. Gray *13-533; 17-474*	2	O
Panicum anceps Michx. subsp. *anceps* *13-462*	1	O
Panicum flexile (Gattinger) Scribn. *13-608; 14-560*	1	I
Paspalum pubiflorum Rupr. ex Fournet *13-615; 14-563*	2	O
***Poa compressa* L. *14-150*	2	I
***Schedonorus arundinaceus* (Schreb.) Dumort *14-171*	14	A
Schizachyrium scoparium (Michx.) Nash *13-532; 17-472*	2	I
Tridens flavus (L.) Hitchc. *13-644*	-	O
SMILACACEAE		
Smilax bona-nox L. *02-395; 17-219*	-	S
DICOTYLEDONAE ANGIOSPERMS		
ACANTHACEAE		
Ruellia caroliniensis (J.F. Geml.) Steud. *14-205*	1	I
Ruellia strepens L. *13-628; 14-229*	2	I
ADOXACEAE		
Sambucus canadensis L. *13-612*	-	R
Viburnum rufidulum Raf. *13-556*	2	I
ALTINGIACEAE		
Liquidambar styraciflua L. *17-201*	-	R
ANACARDIACEAE		
Rhus aromatica Aiton *13-559; 14-161*	2	I
Toxicodendron radicans (L.) Kuntze *13-466; 14-157*	22	F
APIACEAE		
Cryptotaenia canadensis (L.) DC. *14-214*	2	S
***Daucus carota* L. *13-473; 17-470*	10	O
Eryngium yuccifolium Michx. *13-450*	2	S
Sanicula odorata (Raf.) Pryer & Phillippe. *14-217; 17-211*	8	O
Thaspium chapmanii (Coult. & Rose) Small *13-493; 17-216*	4	O
Zizia aurea (L.) W.D.J. Koch *14-147; 17-215*	4	I
APOCYNACEAE		
Apocynum cannabinum L. *13-442*	1	I
Asclepias tuberosa L. *14-220*	-	R
Asclepias verticillata L. *02-397*	-	R
Matelea obliqua (Jacq.) Woods. *13-514; 14-153*	8	O
ASTERACEAE		
Ambrosia artemisiifolia L. *13-479*	9	F
Ambrosia trifida L. *13-461*	2	I
Arnoglossum atriplicifolium (L.) H.E. Robins. *02-394; 13-528*	3	I
Astranthium integrifolium (Michx.) Nutt. *14-143*	3	O
Bidens polylepis S.F. Blake *13-496; 13-630*	4	O
Cirsium discolor (Muhl. ex Willd.) Spreng. *13-471; 14-351*	-	S
Conoclinum coelestinum (L.) DC. *13-517; 14-567*	5	O
Echinacea purpurea (L.) Moench *13-465*	-	S
Erigeron philadelphicus L. *14-140*	2	I
Erigeron pulchellus Michx. *14-149*	1	S
Eupatorium altissimum L. *13-490; 13-606*	1	I
Eupatorium perfoliatum L. *13-477*	1	I
Eutrochium fistulosum (Barratt) Lamont *13-446*	4	O
Helianthus microcephalus Torr. & A.Gray. *13-515*	3	I
Heliopsis helianthoides (L.) Sweet *13-487*	3	O

Lactuca canadensis L. *13-454*	-	S
***Leucanthemum vulgare* Lam. *14-159*	3	I
Packera obovata (Muhl. ex Willd.) Weber & A.Löve *14-146; 17-50*	6	I
Ratibida pinnata (Vent.) Barnhart *13-460*	1	S
Rudbeckia fulgida Aiton *13-485; 14-352*	9	O
Rudbeckia hirta L. *14-352*	-	I
Rudbeckia triloba L. *14-353; 17-482*	8	O
Silphium trifoliatum L. *13-633*	2	O
Smallanthus uvedalius (L.) Mackenzie ex Small *13-470*	6	I
Solidago altissima L. *13-617*	11	F
Solidago caesia L. *13-611*	3	I
Solidago nemoralis Ait. *13-492*	2	I
Symphotrichum dumosum (L.) Nesom *13-610*	-	I
Symphyotrichum lateriflorum (L.) A. & D. Löve *13-631*	1	O
Symphyotrichum patens (Ait.) Nesom *13-521*	1	I
Symphyotrichum pilosum (Willd.) Nesom *13-618*	4	O
Symphotrichum shortii (Lindl.) Nesom *13-642; 17-477*	2	O
Symphotrichum undulatum (L.) Nesom *13-641; 17-484*	2	I
**Taraxacum officinale* Wiggers. *17-49*	-	R
Verbesina alternifolia (L.) Britton ex Kearney *13-609; 17-479*	4	I
Vernonia gigantea (Walt.) Branner & Coville *13-447*	7	O
BALSAMINACEAE		
Impatiens capensis Meerb. *13-468*	-	F
BERBERIDACEAE		
Podophyllum peltatum L. *14-131; 17-53*	3	O
BETULACEAE		
Carpinus caroliniana Walt. *13-561*	2	O
Corylus americana Walt. *13-634*	3	I
Ostrya virginiana (Mill.) K. Koch. *14-367*	2	I
BIGNONIACEAE		
Campsis radicans (L.) Seem. ex Bureau *13-555*	9	O
BORAGINACEAE		
Lithospermum canescens (Michx.) Lehm. *14-137*	5	I
BRASSICACEAE		
***Barbarea vulgaris* Ait. *17-51*	-	R
CAMPANULACEAE		
Campanula americana L. *13-457; 14-354*	-	R
Lobelia inflata L. *13-643*	1	S
Lobelia siphilitica L. *13-459; 17-000*	2	O
Lobelia spicata Michx. *02-393; 13-523*	3	S
CANNABINACEAE		
Celtis occidentalis L. *13-546*	1	I
Celtis tenuifolia Nutt. *13-622*	1	S
CAPRIFOLIACEAE		
***Lonicera japonica* Thunb. *13-607; 17-207*	11	F
CELASTRACEAE		
***Celastrus orbiculatus* Thunb. *13-541; 17-208*	2	O
CONVOLVULACEAE		
Calystegia sepium (L.) R. Br. *13-441; 14-359*	8	O
Cuscuta coryli Engelm. *17-469*	-	R

CORNACEAE		
Cornus drummondii C.A. Mey. *14-565*	-	R
Cornus florida L. *13-545; 17-47*	3	I
EBENACEAE		
Diospyros virginiana L. *13-566*	1	S
EUPHORBIACEAE		
Euphorbia corollata L. *13-474; 14-355*	6	I
FABACEAE		
Amphicarpaea bracteata (L.) Fernald *13-469; 17-475*	17	F
Cercis canadensis L. *13-549; 17-46*	8	O
Chamaecrista fasiculata (Michx.) Greene *13-480; 14-358*	11	O
Desmodium glabellum (Michx.) DC. *13-489*	11	O
Desmodium paniculatum (L.) DC. *13-499; 14-562*	15	O
Lespedeza repens (L.) Bart. *13-453*	4	I
***Medicago lupulina* L. *14-170; 17-209*	-	S
***Melilotus alba* Medik. *13-451*	-	S
***Melilotus officinalis* (L.) Lam. *17-206*	-	S
Robinia pseudoacacia L. *13-564*	2	O
***Trifolium pratense* L. *14-175; 17-476*	1	I
***Vicia sativa* L. ssp. *nigra* (L.) Ehrh. *14-133; 17-210*	-	S
FAGACEAE		
Fagus grandifolia Ehrend. *13-558*	1	I
Quercus alba L. *13-613*	2	I
Quercus falcata Michx. *17-202*	-	S
Quercus imbricaria Michx. *13-565*	1	S
Quercus muhlenbergii Engelm. *13-554*	2	I
Quercus rubra L. *13-548*	7	O
Quercus velutina Lam. *13-544*	2	I
GENTIANACEAE		
Gentiana flavida A.Gray *02-392; 12-1144; 17-480*	30	F
Gentianella quinquefolia (L.) Small *12-1146*	2	S
Sabatia angularis (L.) Pursh *14-356*	-	R
JUGLANDACEAE		
Carya cordiformis (Wangenh.) K. Koch *13-568*	-	S
Carya ovata (Mill.) K. Koch *13-621*	-	I
Juglans nigra L. *13-619*	1	R
LAMIACEAE		
Collinsonia canadensis L. *13-536*	1	I
Cunila origanoides (L.) Britton *13-443*	2	I
***Glechoma hederacea* L. *13-520*	4	F
Lycopus virginicus L. *13-475*	-	I
Monarda fistulosa L. *13-464*	1	I
Physostegia virginiana (L.) Benth. *13-455; 14-362*	6	O
**Prunella vulgaris* L. *13-482; 14-360*	2	I
Pycnanthemum pycnanthemoides (Leav.) Fernald *14-357*	2	O
Salvia lyrata L. *14-135*	-	I
Scutellaria incana Biehler *17-471*	-	S
Scutellaria nervosa Pursh *14-126*	4	I
MYRSINACEAE		
Lysimachia lanceolata Walt. *13-531; 14-210*	2	I
Lysimachia quadrifolia L. *13-623; 14-178*	8	O

OLEACEAE		
Fraxinus americana L. *13-542*	9	O
Fraxinus quadrangulata Michx. *13-635*	3	S
ONAGRACEAE		
Gaura biennis L. *13-484; 14-569*	-	I
Ludwigia alternifolia L. *13-452*	-	I
OROBANCHACEAE		
Pedicularis canadensis L. *13-495; 14-128*	-	I
OXALIDACEAE		
Oxalis grandis Small *13-632; 14-164*	2	O
PHYRMACEAE		
Mimulus alatus Aiton *13-458*	2	S
PLANTAGINACEAE		
Penstemon digitalis Nutt. ex Sims. *14-154; 17-221*	-	I
Plantago rugelii Decne. *13-519*	1	I
PLATANACEAE		
Platanus occidentalis L. *13-638*	1	S
POLEMONIACEAE		
Phlox divaricata L. var. *divaricata* *17-48*	-	I
Phlox glaberrima L. *14-163; 17-225*	-	S
Polemonium reptans L. *17-42*	-	R
RANUNCULACEAE		
Anemone virginiana L. *13-445; 14-21*	10	I
Clematis virginiana L. *13-552*	2	I
Thalictrum revolutum DC. *14-168; 14-169*	13	F
Thalictrum thalictroides (L.) Eames & Boivin *17-41*	-	S
RHAMNACEAE		
Rhamnus caroliniana Walt. *13-547*	3	I
ROSACEAE		
Agrimonia parviflora Aiton *13-467*	3	O
Agrimonia rostellata Wallr. *13-478*	8	O
Fragaria virginiana Dcne. *13-494*	12	O
Geum canadense Jacq. *13-483*	7	I
Physocarpus opulifolius (L.) Maxim. *17-200*	-	R
Potentilla simplex Michx. *13-538; 14-136*	7	O
Prunus serotina Ehrh. *13-560*	-	I
Rosa carolina L. *13-543; 14-176*	3	I
Rosa setigera Michx. *13-620; 14-213*	2	S
Rubus argutus Link *13-569*	1	O
Rubus flagellaris Willd. *14-125*	2	I
RUBIACEAE		
Galium circaezans Michx. *13-539; 14-215*	1	I
Galium triflorum Michx. *14-124*	2	O
Houstonia canadensis Willd. ex Roemer & Schultes. *14-148*	-	I
SALICACEAE		
Salix nigra Marsh. *14-223*	-	R
SAPINDACEAE		
Acer saccharinum L. *13-614*	-	R
Acer saccharum Marsh. *13-562*	2	I
SOLANACEAE		
Solanum carolinense L. *13-529; 14-212*	1	R

THEOPHRASTACEAE		
Samolus parviflorus Raf. *13-481*	-	R
ULMACEAE		
Ulmus americana L. *14-231; 14-570*	2	S
Ulmus rubra Muhl. *13-567; 14-129*	5	O
VERBENACEAE		
Verbena urticifolia L. *13-472*	-	I
VIOLACEAE		
Viola hirsutula Brainerd *17-52*	-	I
VITACEAE		
Parthenocissus quinquefolia (L.) Planch. *13-624*	15	F
Vitis aestivalis Michx. *14-177; 17-213*	3	O

(*) Naturalized taxon; (**) Invasive pest plant taxon (KY-EPPC 2013)